Multilevel Models with Latent Variables

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Traditional Strengths of Multilevel Models

- Explicitly account for the interdependence of clustered units (where clustering may be spatial or temporal).
- Allow for the modeling of both average (fixed) effects and individual (random) effects.
- Permit inferences to be drawn to broader populations.
- Example: School-based substance use intervention study.
    - The substance use of students may be correlated within schools.
    - We may be interested in whether the effect of the intervention varies over schools (is random).
    - We would like to make inferences from the sample of schools present in the study to all schools.

Traditional Strengths of Latent Variable Models

- Latent variables represent the constructs we <u>want</u> to study in terms of the observable variables we <u>can</u> study.
- Latent variable models provide a means to parse out measurement error by combining across observed variables (using correlations among vars) and allow for the estimation of complex causal models.
- Latent variable models are well developed for metric and discrete observed variables (including SEM and IRT approaches).
- Example: Depression
    - Observed variables might be: Sadness, Trouble Sleeping & Lethargy.
    - All are indirect markers of depression, but none is a perfect measure of the construct.
    - Each is measured with error yet we would like predictions of depression by other variables to be unbiased.

Are Multilevel Models Really Latent Variable Models?

- Although seemingly discrepant, multilevel models invoke similar assumptions to latent variable models.
    - The random effects are never actually observed, but must be inferred from the covariance among observations within clusters.
    - Like most latent variables, the random effects are arbitrarily assumed to be normally distributed (or sometimes discretely distributed as in latent class models).
    - Like most latent variable models, multilevel models typically assume that the random effects are uncorrelated with the residuals.
- Indeed, multilevel linear models can be identically estimated as SEMs (Bauer, 2003; Curran, 2003; Skrondal & Rabe-Hesketh, 2004).
- Similarly, IRT models can be reframed as nonlinear mixed models for discrete outcomes (Rijmen et al. 2003; Skrondal & Rabe-Hesketh, 2004; Van den Noortgate et al. 2003)

Hybrid Models

- The realization that traditional multilevel models and latent variable models are analytically similar (and in many cases identical) has lead to the development of a new class of hybrid models.
- Multilevel models can be estimated that include latent variables combining across items via either factor analytic or item response theory formulations.
- Multilevel models can include complex causal pathways (e.g., mediational chains) among observed or latent variables.
- Latent variable models can account for nesting or clustering effects and can include random effects
    - Multilevel SEM
    - Multilevel IRT
- These hybrid models are at the forefront of psychometric research, bringing the best of both models together.

Software Development

- Multilevel latent variable models have been implemented in at least two widely available software packages:
    - The free Stata-based macro, GLLAMM, of Skrondal & Rabe-Hesketh
    - The commercially available stand-alone software, Mplus, of Muthen & Muthen.
    - Less far-reaching implementations of multilevel latent variable models are available in the commercial programs LISREL and EQS.
- Of course, the day after I give this talk, the statements made above will be completely erroneous and outdated (maybe they already are?).
- The pace of software development for these models in the last two or three years has been rapid!

Stepping Back…

- In many cases, the pace of software development has outstripped the ability of researchers to investigate, evaluate and sometimes even conceptualize the models!
    - For instance, what does it mean for a factor loading to be a random effect? That the measurement properties of the item are unique to the individual? Is this a good or bad thing?
- New developments are often not peer-reviewed, but rather published in software manuals, books, and invited book chapters.

A Call for Research

- There is clearly a need for additional peer-reviewed research to
    - Think philosophically about new modeling possibilities.
    - Conduct analytical research to better understand the models, their promises and problems, and where improvements can be offered.
    - Conduct simulations to evaluate model performance in finite samples and when assumptions are unmet.

Closing Thoughts

- Multilevel models and latent variable models are sufficiently similar that hybridizations are possible and potentially quite useful.
    - Multilevel linear models and SEM
    - Multilevel nonlinear models and IRT
- Although these developments are exciting, they are taking place largely outside of the mainstream body of scientific research – in software manuals, books and book chapters.
- There is a need for quantitative researchers to catch up to software development – to think hard about the meaning of the models, their unique affordances and flaws, to further improve the application of these models in practice.